

Research for a society in change



Water
Energy
Mineral resources
Nature

Annual report 2006
Geological Survey of Denmark and Greenland
Ministry of the Environment



GEUS'

new place in the research landscape

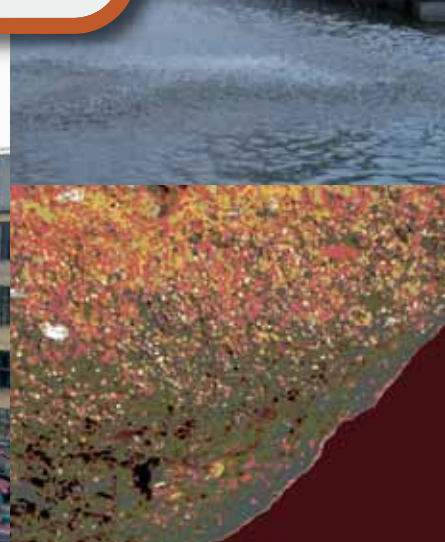
In 2006, the Danish government presented a plan to reduce the number of universities and sector research institutions in Denmark to fewer, but larger research institutions, which will have a strong position internationally. The existing research institutions, including GEUS, were asked to analyse and document merger potentials and submit their findings and requests.

Over the summer, negotiations were carried out between the University of Copenhagen, the University of Aarhus and GEUS about GEUS' future place in the research landscape, and meetings were held between the parties involved and the Ministry of Science, Technology and Innovation.

In October, the Minister for Science, Technology, and Innovation informed the Chairman of the Board of Directors that the government had decided that:

- GEUS was to be reorganised as an independent research institution with a new Board of Directors;
- the Geocenter Denmark model, which entails binding collaboration between the new institution, the University of Copenhagen and the University of Aarhus, was to be realised;
- the reorganisation was to be carried out as quickly as possible during the course of 2007, and that the Minister for the Environment would present a separate Act on this in 2007.

As a basis for its decision, the government stated that GEUS has special official responsibilities including the mineral resources area as well as cooperation with Geological Institutes and Surveys in other countries. GEUS provides a comprehensive geological research environment that is the largest in Denmark, and its work in Greenland is of fundamental importance to the Realm of Denmark, e.g. in relation to the Continental Shelf Project.



Introduction

The most important event for GEUS in 2006 was the government's decision on GEUS' future role and position in connection with the reorganisation of the national research landscape in Denmark. The government granted GEUS' request to remain an independent research institution under the Ministry of the Environment. However, GEUS will also be obliged to contribute its specialist expertise to the PhD, Master and Bachelor programmes at the universities. Collaboration with the universities must be intensified in the framework of a new Geocenter Denmark. This new centre will bring together GEUS and the two universities in Copenhagen and Aarhus, which have educational programmes for geologists, under one common umbrella.

Another significant innovative feature related to implementation of the municipal structural reform. GEUS received a number of new employees that were transferred from the counties to a new GEUS department in Aarhus. The new department's main assignment is to manage coordination of the fee-financed survey of Danish groundwater resources.

In connection with the municipal structural reform, GEUS has contributed to the establishment of Denmark's Environmental Portal. GEUS' databases have been developed as common public, online databases for the registration of data on borehole drillings, groundwater and drinking water, as well as geophysical data which are crucial for water and mineral resources management.

In the area of climate, GEUS has contributed with research in three important fields. By means of a model developed by GEUS, calculations have been made on the effect of climate change on the fresh-water cycle in Denmark. These calculations show large regional variations of significance to the future management of water resources and the aquatic environment.

The melting of the Greenland ice sheet constitutes a factor of uncertainty in international model calculations of the future global increase in sea level. On

the basis of a pilot study completed in 2006, GEUS launched a new monitoring programme, which, over a number of years, is to assess the mass loss from the border zone of the inland ice sheet and from calving icebergs. This will be achieved by setting up fully automated measuring stations that will register the melting process, climate parameters and the rate by which the ice moves.

With a view to limiting global emissions of greenhouse gases into the atmosphere, together with a number of European countries GEUS has carried out research projects to clarify the possibilities of storing CO₂ underground. Storage of CO₂ will commence near Berlin in 2007.

In the area of energy, research by GEUS has contributed to increased interest in Greenland from the international oil industry, which has resulted in a number of licence applications in connection with a licensing round that covered areas offshore West Greenland. In Danish territories, GEUS has demonstrated the existence of possible new deposits of gas/condensate formed from deep-lying carboniferous coal beds in the Danish Central Graben and in surrounding areas.

In 2006, surveys of the continental shelf north of Greenland commenced for real. The objective is to make potential territorial claims beyond 200 nautical miles where oil and gas deposits might exist. Despite extreme and unfavourable weather and ice conditions, Danish and Canadian researchers together succeeded in collecting enough data to establish a seismic model of the subsurface.

GEUS' geological surveys in Greenland are an essential condition for the great, international interest which in recent years has entailed the most extensive commercial mineral exploration ever. Efforts by GEUS were aimed especially at the Nuuk and Maniitsoq areas, with special focus on gold and diamond potentials.



Per Buch Andreasen
Chairman
of the Board of Directors



Martin Ghisler
Managing Director,
2006



Johnny Fredericia
New Managing Director,
2007

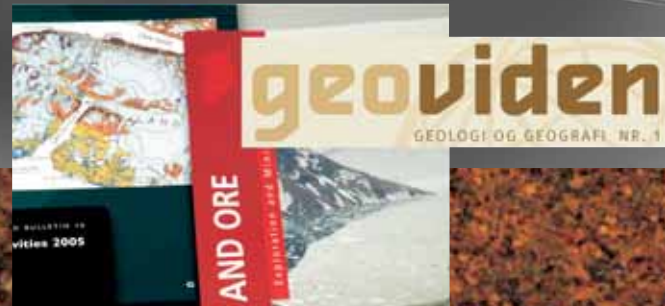
Databanks

Towards a national database with increased access

As a step in the municipal structural reform, it was agreed that in future GEUS' Jupiter database is to be a common public database of data on drillings, groundwater and drinking water. In future, environment employees in municipalities, regions and environment centres will be working online with data in Jupiter. During 2006, in close collaboration with the counties, GEUS carried out extensive work to harmonise and convert data from all county databases to Jupiter, so that data in the future will be available from a single source and in a uniform format. The data in question include geological data from drillings, and data on groundwater resources and water chemistry, which the new authorities and environment centres will need in their management of the environment, groundwater, drinking water and mineral resources. Several new types of data from the counties have been entered in the Jupiter database during the course of the year. This is e.g. sample data from pumping tests for selected aquifers, as well as sedimentary-chemical analyses, age determination of groundwater and printed drilling reports, which are scanned into the database. GEUS has also worked to increase the availability of data in Jupiter. A new format for data extraction has been developed covering nearly the entire data content in Jupiter, and extractions from the database were made free of charge from 2006. Furthermore, a new interface has been developed for the Jupiter database consisting of a number of so-called web services for data extraction and updating. The purpose of these changes is, amongst other things, to make it possible for groundwater systems such as Rambøll's GeoGIS, Geokon's GeoEnviron, and KMD's Struktura to function online with the database. Finally in 2006, GEUS continued training well drillers in digital reporting of drilling data to Jupiter. This work is progressing satisfactorily and more than 60 percent of data from water supply wells are now reported digitally.

Storage of important continental shelf data

The Continental Shelf Project got going for real after Denmark ratified the United Nations Convention on the Law of the Sea in 2004. The project is collecting data about seabed depth and geology in order to be able to document Denmark's possible claims to an expansion of the relevant continental shelf areas beyond the 200 nautical mile limit in the waters around the Faeroe Islands and Greenland. Access to possible underground and seabed resources is at stake, and since 2003, data have been pouring in from surveys of the five potential areas offshore the Faeroe Islands and Greenland for which claims may be made. The large quantities of different and very complex geodata, which have been collected during expensive ship and field expeditions, require careful storing and systematisation. In 2006, GEUS continued its work to construct a database for the Continental Shelf Project, including GIS features and other auxiliary systems. This database is an important tool for the project and will play a significant role for documentation efforts to support possible claims for expansion of Denmark's continental shelf. The work is progressing as expected and the database is now able to manage e.g. geodetic, bathymetric, seismic, gravimetric and magnetic data.



Scientific results
Review of Survey activities

Den dynamiske jord

Den VERDEN AF MINERALER

jord

GEOLOGY AND ORE

and information

Storage, quality assurance,
and presentation of geological
knowledge and data



Focus on increasing the intake of geology students

The intake of geology students at Danish universities has slowed down noticeably over recent years. At the same time, society increasingly needs geologists to solve environmental tasks and tasks in the water sector and in the oil and mineral resources industry. During 2006, GEUS participated in a number of measures aimed at upper secondary schools to boost the intake of students at university. In collaboration with the other parties in Geocenter Copenhagen, during the course of the year, new experimental teaching materials were developed (GeoCase), for teaching natural sciences at upper secondary school level. Furthermore, a total of four editions of the easy-to-read popular-science magazine Geoviden (Geo Science) were published during the year. The magazine is being read by an ever greater number of teachers and students at Danish upper secondary schools. The schools now also have increased access to teaching material via the GEUS website, where a new section containing easily accessible knowledge on earthquakes was launched in collaboration with the Danish National Space Center. Finally, geologists from GEUS participated in 'Mini Science Camp 2006', where school students visited the Department of Geography and Geology at the University of Copenhagen. GEUS is also offering several courses with further training for upper secondary school teachers in collaboration with the Association of Geography Teachers and other Danish geo-professional associations.

Expansion of a nationwide geophysics database

The nationwide geophysics database for the environment and mineral resource area, GERDA, is under continued development. The GERDA database contains different geophysical data, mainly from mapping by counties of areas of special drinking water interest, as well as GEUS' water supply well logging. Data include geoelectric and electromagnetic data such as TEM data and logs, older Wenner and Schlumberger geoelectric data, PACES and MEP data. Both measurement data and interpretations are stored as geophysical models, and at present there are about 180,000 models in the database. The GERDA database plays an important role in the management of water resources and mineral resources, and it will continue to be an important tool and library for future fee-financed groundwater mapping by the environment centres in future. During 2006, the database was developed further, so that, now, it also handles SkyTEM data collected by helicopter, and the features for managing log data have moreover been improved. GERDA was developed in close cooperation with the University of Aarhus, Aarhus County, the Danish Forest and Nature Agency, and consultancies.

New book

about Greenland's minerals

'En verden af mineraler i Grønland' (a world of minerals in Greenland) is the title of a new popular-science book from GEUS, which came out in 2006. This book is a presentation of Greenland's singular wealth of minerals illustrated with almost 200 colour pictures and containing descriptions of history, systematic and place of discovery. A total of 32 minerals are described in detail along with 30 topics and stories about Greenland's minerals and their significance for modern Greenland. The book is aimed at people with an interest in the mineral resources of Greenland, the building blocks of nature, and in how we exploit the Earth. Moreover, there is inspiration for teachers of geography and earth sciences. 'En verden af mineraler i Grønland' was well-received by critics. The Greenlandic newspaper 'Grønlandsposten' said in its review: "How pleasing to read about the different stones described in the book without having to make an effort to understand the text; the minerals have been popularised very successfully." The book has been published in Danish only.



The effect of climate change on the water cycle

In 2006, GEUS calculated the impact of climate change on the freshwater cycle in Denmark for the Danish Environmental Protection Agency. These calculations were carried out for two climate scenarios from the Danish Meteorological Institute using the so-called DK model developed by GEUS. It is the first time that the signals from the climate models have been integrated with the national hydrological model, which is able to describe in detail how climate change affects the entire water cycle - geographically, at different depths, and in relation to time. The calculations reveal a significant impact on the water cycle in Denmark, with large regional and seasonal variations. For example, the model shows that available water resources will increase in west Jutland, and that there should be no problem covering future water requirements if they remain the same as today. However, the calculations also suggest that river valleys and low-lying areas will suffer from lack of water for large parts of the year, with a resulting detrimental effect on agriculture. In Zealand, the most severe effect of climate change will be a marked prolongation of the period with low run-off in the water courses. The purpose of the study has been to quantify the future groundwater recharge, the determination of the groundwater level, the groundwater pressure in the deeper-lying reservoirs, as well as watercourse run-off. All are important parameters for good, future management of water resources and the aquatic environment, and interest in the work with the model has consequently been substantial. Toward the end of the year, GEUS commenced a similar survey which incorporated landuse and sea-level rise for the Danish Water and Waste Water Association (DANVA) and the Copenhagen-based utilities company, Københavns Energi.

Sustainable water abstraction of deep groundwater in the limestone

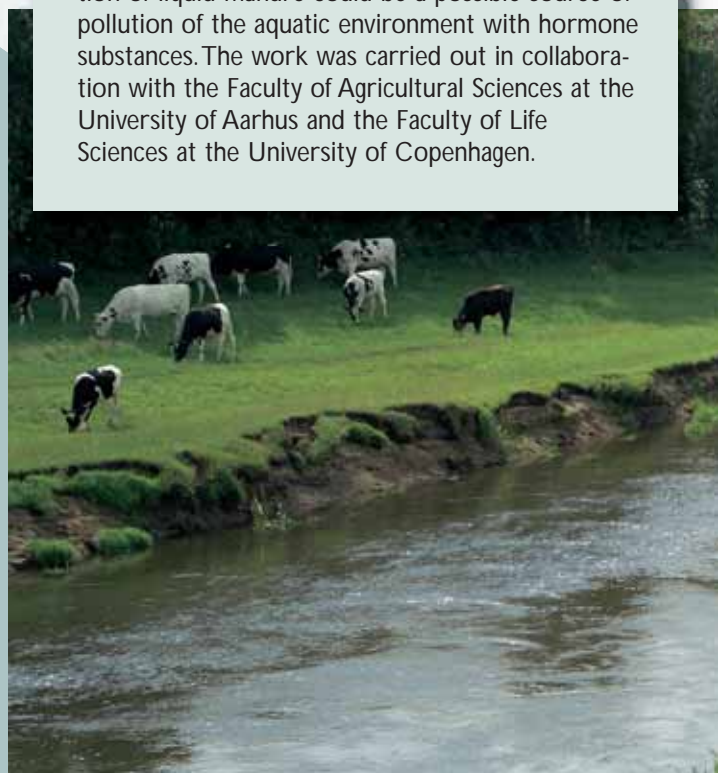
Due to the percolation of polluting substances, we can anticipate increasing problems with the water quality in many water wells in north-east Zealand, where water abstraction is from the uppermost jointed limestone strata. In recent years, there have thus been attempts at finding deeper and better protected groundwater resources in the limestone. In some places, the search has been successful, but in others, problems with saltwater in the wells have been a stumbling block. In 2006, GEUS completed a project stretching over several years, which has provided knowledge about the possibilities for water abstraction from the deeper strata of the limestone without influencing the stability of the interface between freshwater and the underlying salt water. The project mapped the depth and characteristics of the saltwater/freshwater interface and examined the processes that define the location of the interface. The results identify areas in northeast Zealand with particularly favourable conditions for abstracting the deep groundwater in a sustainable manner. The results also outlined the processes that influence the assessment of the temporal development of the salt loading of wells. Furthermore, the project has contributed new knowledge about the suitability of different methods for mapping the saltwater/freshwater interface and provides recommendations on how best to organise drilling surveys to map the interface. The project was carried out with Environment & Resources at the Technical University of Denmark and was funded by Københavns Energi, Copenhagen, Roskilde and Frederiksborg counties.

Water

Procurring knowledge to permit optimal management of our water resources

Oestrogen run-offs from liquid manure into the aquatic environment

For many years, we have known that the application of liquid manure to fields can lead to the negative addition of nutrients to the aquatic environment; however, no survey has been made to clarify whether hormone substances in livestock manure may also have a negative impact. Sows and hogs naturally produce the sex hormone oestrogen, which is secreted through manure. In the past, the belief was that oestrogens were either bound to the soil or degraded. In 2006, GEUS presented new results which show that oestrogens from manure can run off into the aquatic environment. In two trial fields with moraine clay in Jutland, liquid manure was applied as part of normal farming operations. In both fields, measurements later showed that oestrogens run off into the aquatic environment in concentrations that may lead to hermaphroditism in fish. Up to three or seven months after application of the manure, oestrogens were still found in high concentrations in the drainage water from the fields. This is the first time, under actual field conditions, that it has been demonstrated that application of liquid manure could be a possible source of pollution of the aquatic environment with hormone substances. The work was carried out in collaboration with the Faculty of Agricultural Sciences at the University of Aarhus and the Faculty of Life Sciences at the University of Copenhagen.



resources

New tools for managing water resources

The EU Water Framework Directive sets out requirements for overall management of water resources that caters for groundwater, surface water and e.g. socio-economic aspects. Hydrological models linking groundwater and surface water are used in resource management, and there is increasing demand for quality assurance of the use of these models. In 2006, the GEUS-run EU project HarmoniRIB was completed. This project has developed methods to assess the uncertainty of water data and models. The results are available at the website of the project: www.harmonirib.com. Here you can find e.g. the software tool DUE, which helps users describe and assess the uncertainty of data. Furthermore, a number of guidelines have been prepared on how to assess uncertainties and incorporate them in decision-making processes in connection with water management. Finally, the project has gathered data containing information on uncertainties in a database from eight representative catchment areas in Europe. The database can be used freely for research purposes, and the project researchers are currently in dialogue with the European Environment Agency on takeover of the database. In September 2006 at a workshop in Brussels, the project results were presented to key persons working with water management in Europe.

A map of pesticide-sensitive sandy soil

The general sensitivity of sandy soil to pesticide leaching can be explained by the soil's content of humus, clay and silt. This is one of the main conclusions of the KUPA project, which GEUS and the Faculty of Agricultural Sciences at the University of Aarhus completed in 2004. The project shows how to calculate sensitivity on the basis of knowledge about the few, simple soil parameters. Since then, the parties involved in the project have carried out a number of demonstration projects on sandy soil at different locations throughout Denmark. In collaboration with the Jutland counties of Ribe, Aarhus and Northern Jutland, tests were made to ascertain whether it is practicable to identify especially sensitive sandy soil at farm level. Since the data coverage at national level consists of point data, it was necessary to use statistical methods in order to describe the geographical distribution of the soil properties. The tests were successful, and during 2006, GEUS and the Faculty of Agricultural Sciences presented a map of all Danish sites with sandy soil sensitive to pesticide leaching. The map is based on information from different maps of soil-types and soil-conditions and information in the texture database. The basis for the map can be improved e.g. by adding new soil data and interpreting texture conditions relative to topography.



Procuring of knowledge for continued exploration and exploitation of energy resources in Denmark and Greenland



Energy



Go-ahead for delimitation of the continental shelf in the Arctic Ocean

In 2004, Denmark ratified the United Nations Convention on the Law of the Sea, which provides opportunity for making claims to subsurface and seabed resources beyond 200 nautical miles. A requirement for any claim is that there is a natural prolongation of the land territory beyond 200 nautical miles, and GEUS has since been busy collecting and interpreting data from the five areas offshore Greenland and the Faroe Islands where there is potential for making claims. In 2006, work on a delimitation of the continental shelf in the Arctic Ocean commenced for real. In April/May, Danish and Canadian researchers worked together to collect refraction-seismic, sea-depth and gravity field data above the submarine Lomonosov Ridge. The Ridge stretches into the Polar Sea north of Ellesmere Island and Greenland, and, here, both Denmark and Canada can make claims for extension. The Geological Survey of Canada (GSC) and GEUS worked together on collecting the necessary data from this inhospitable area. All the expertise available was needed, as both weather and ice conditions were very unfavourable for the work on the sea ice. Despite relentless weather gods, the researchers succeeded in collecting sufficient data for setting up a seismic model of the subsurface, from the inner shelf near Greenland's coast and some distance into the Lomonosov Ridge. In 2006, GEUS also finished interpreting data from the area southwest of the Faroe Islands and carried out seismic data collection offshore South Greenland. The Continental Shelf Project is being funded by the Ministry of Science, Technology and Innovation with contributions from the Faroese Home Rule Government, and is a collaboration project between GEUS and other institutions from Denmark, the Faroe Islands, and Greenland.



New European initiatives in CO₂ storage

Reduction of atmospheric CO₂ emissions is now a hot item on the political agenda. One way to reduce emissions is to store the greenhouse gases underground. In 2006, GEUS took part in a number of EU-funded international research projects to clarify the possibilities for geological storage of CO₂. Researchers under the CO₂SINK project have been busy with the final surveys of the geology at Ketzin near Berlin, where CO₂ will be stored in the subsurface in 2007. Furthermore, in the ULCOS project, which is to develop methods for halving CO₂ emissions from the steel industry in Europe, researchers have worked to identify suitable locations for geological storage of greenhouse gas near four of the largest steel plants in the EU. Three new EU projects were launched in 2006. These are the DYNAMIS project, which is to pave the way for future European gas or coal-fired power plants that produce hydrogen and electricity without emitting CO₂, and the GEUS-managed project GeoCapacity, which is to update and expand the basis for geological storage of greenhouse gas throughout Europe. Finally, the latest project, called COACH, is to transfer competences in geological storage of CO₂ from the EU to China. Knowledge from the research projects is put into play in international fora where GEUS is represented. In connection with the EU's 7th Framework Programme for Research and Technological Development, GEUS is participating in the European Technology Platform on Zero Emission Fossil Fuel Power Plants (ETP ZEP), which advises the EU on content and strategy for research into CO₂ matters. GEUS is also taking part in the technical work in the global Carbon Sequestration Leadership Forum and represents the EU in a Task Force concerning standards for estimating CO₂ storage capacity.



resources



Successful licensing round in Greenland

For many years, GEUS has been working to set up scientifically well-founded, oil-exploration models in order to attract investment from international industry to Greenland. In collaboration with the Bureau of Minerals and Petroleum, GEUS has moreover taken part in the development of exploration strategies and marketing of Greenland as a potential oil area. This work produced results in 2006 during the licensing round for the offshore area west of Disko-Nuussuaq in West Greenland. By the close of the licensing round in December, the Bureau of Minerals and Petroleum had received applications from Exxon, Chevron, Husky and DONG. Prior to this successful licensing round, geologists from GEUS had worked intensively to interpret and analyse data from the area, in order to evaluate the exploration potential. This work included, in particular, interpretation of seismic and other geophysical data with a view to adjusting the structural models and analyses of source and reservoir rocks and oil seeps. GEUS then prepared a new structural model for the licence area and a GIS model with all relevant exploration data. The results of the work were presented at numerous meetings with oil companies during the spring and autumn of 2006. At the opening meeting of the licensing round in Ilulissat in June, no less than 12 international oil companies participated in the events spanning several days and including presentations and a field trip to Disko and Nuussuaq.



Hydrocarbon resources in North Sea chalk

Denmark is pumping oil and gas from the North Sea worth billions, and hydrocarbons have secured the supply of energy to Danish society for many years. The hydrocarbons are present in the highly porous layers in the chalk, and geological knowledge from many years of exploration and extraction has led to continuous, new findings. In 2006, GEUS worked to improve our existing knowledge about the structure of the chalk in the Danish Central Graben, in order to identify new hydrocarbon-bearing layers in the chalk. Efforts included a revised lithostratigraphic division of the chalk into more than 90 exploration boreholes, as well as examinations of the regional distribution of the different chalk units, their extent and thickness. The purpose of the work is to localise the porous layers in the chalk which could have reservoir properties and to find evidence for possible hydrocarbons.

Possible gas/condensate from deep sources in the North Sea

Rising oil prices and the developments in drilling techniques have created increased interest in possible deep oil deposits generated by deeplying source rocks. For several years, GEUS has carried out research into the processes that generate oil and gas from different types of source rocks. During 2006, a study was completed of the possibilities for generating oil and gas from lower, carboniferous coal beds in the North Sea, which is a likely Paleozoic hydrocarbon source. The study included chemical and petrographic analyses of the deep coal beds in the Gert-2 well in the Danish Central Graben and a Norwegian well close by. The study shows that the coal beds are only able to generate gas/condensate, and this has something to do with the chemical structure of the original vegetation that formed the coal beds. In other words, gas/condensate can be expected, if one goes after plays with a deep Carbon source in the Central Graben. The thin coal beds in the Gert-2 well cannot generate hydrocarbons in financially viable quantities. However, if thicker carboniferous lower coal beds exist in a larger area, they could potentially be a source of gas/condensate in the Danish Central Graben and surrounding areas.



Mapping and evaluation

of resources

Detailed geological maps are an important tool for mining companies in their exploration activities. During the summer of 2006, GEUS continued the detailed, 1:100 000 scale mapping of Greenland, concentrated in areas where mineral resources interests are greatest. Also in 2006, geologists mapped areas around Kapisillit at the bottom of the Godthåb Fjord. Several maps were published during the course of the year. These include a geological map of north Ikamiut ('Ikamiut, 68 V.1 Nord') in the scale of 1:100 000, and a thematic map of geological profiles of the basalts on the Nuussuaq peninsula in West Greenland as well as a description for the Thule map sheet from North Greenland in the nationwide map sheet series in the scale 1:500 000. Concurrently with the mapping, ore geologists completed an evaluation of resources in the southern part of West Greenland. This means careful processing of the results of all company activities in the area and special, targeted field studies. In particular, the geologists had their eyes on the so-called Precambrian supracrustal rocks, as these rocks are typical host rocks for gold and nickel mineralisations. With financial support from the Bureau of Minerals and Petroleum, three such geological environments in the Nuuk-area were examined in detail. General studies of geological environments in Greenland and their mineral deposits were continued in 2006. Finally, ore geologists followed up on last year's discovery of a new carbonatite deposit in the Nuuk region. Studies showed that this deposit is rich in the mineral apatite, which, amongst other things, is used in artificial fertilisers, and that it contains zones enriched with rare minerals.

Mineral deposits in 3-D

In 2004, Greenland's first gold mine opened in Nalunaq in South Greenland, and the year after the Seqi olivine mine opened near Nuuk in West Greenland. A good three-dimensional image of mineral deposits is an important tool to understanding minerals' formation, or for monitoring the progress of a mining activity and assessing how the deposit may be emptied. Here, society has an obvious interest that it should pursue. In practice, geologists only have sporadic information about the distribution of mineral occurrences from boreholes in the rock or from observations on the surface or in mine tunnels. With the help of computer calculations, GEUS is working together with the Bureau of Minerals and Petroleum on the construction of three-dimensional models of the mineral deposits currently being mined. In 2006, work concentrated on creating 3-D models of the deposits in the Nalunaq and Seqi mines in Greenland. A model for the as yet unexploited zinc deposit at the Citronen Fjord in North Greenland is also under way. Experience from constructing 3-D models is important for supervision tasks and mineral research in Greenland and can also be applied when e.g. extracting gravel and sand in Denmark and assessing the impact on the landscape.

Mineral

Creating the scientific basis for targeted and environment-friendly exploitation of mineral deposits in Greenland and Denmark



Sustainable exploitation of raw materials in Denmark

Denmark is self-sufficient in raw materials for building and construction projects and also has some production of industrial minerals and other products based on these. There is an increasing need for raw materials exploitation that takes account of other interests of nature and society. Denmark's large consumption of raw materials for construction is mainly covered through the production of land-based resources, and less so by marine resources. As a part of the development of sustainable raw materials exploitation, in 2006 GEUS carried out a pilot project in Storstrom County in collaboration with the Forest and Nature Agency. This project engaged in the coordination of raw materials extraction at sea and on land, a coordination which does not exist today, and prepared a statement of the volume and quality of the resources on the basis of existing knowledge. The work led to a recommendation of more long-term mapping of the resources in future.

Increased diamond potential in Greenland

An increasing number of diamond discoveries are being reported in Greenland and, in January 2007, the company Hudson Resources Inc. announced the discovery of a 2.4 carat diamond, the largest found in Greenland so far. In recent years, GEUS has followed up on the work of diamond exploration companies with scientific surveys of the diamond-bearing kimberlite rocks in Greenland. 2006 concentrated on surveys in the diamond area at Maniitsoq in West Greenland, where several new kimberlite sheets with diamond potential were discovered, and the area of interest was enlarged. The field season also offered surprises, as one of GEUS' field groups stumbled upon a new discovery of loose kimberlite boulders during their surveys, near a large nunatak in the ice sheet south-east of Nuuk. The source of the boulders is still unknown, since no fixed kimberlite has been seen in the area. This surprising discovery opens a whole new area for diamond exploration, since there have been no kimberlite findings in this part of Greenland previously. Finally, in 2006 GEUS published a report that presents the discoveries of indicator minerals for kimberlite and two micro diamonds in former river beds on the eastern part of Disko in West Greenland. A licence has been taken out for the area and a company is planning to test the potential.

resources

Increasing interest in Greenland's minerals

For many years, GEUS has collaborated with Greenland's Bureau of Minerals and Petroleum on marketing Greenland's mineral resources. In addition to preparation of information material on the basis of the companies and GEUS' own efforts, Greenland's mineral potential is being marketed at presentations at annual industry exhibitions in Canada. Here, investors and the mining industry meet to visit exhibitions by participating countries and companies in order to evaluate the potential for investments in the exploration and mining sector. During the important 2006 mineral resources exhibitions in Vancouver and Toronto with up to 15,000 visitors, the Bureau of Minerals and Petroleum and GEUS perceived an increased interest in the potential for mineral resources exploration and mining in Greenland, even when considering the generally increasing trend at global level. It was confirmed that, following the many years of marketing efforts, Greenland now has a clearly understood position in the consciousness of the international exploration and mining industry. Many companies are already planning drilling programmes in their licence areas in Greenland, and several have applied for new licences; and even more companies may join the queue. In 2006, GEUS saw an increase in the number of requests from industry for data, maps and knowledge, and many companies have visited GEUS to acquire further geological insight into Greenland's great potential.



Geological maps for planning and management

Geological maps are important tools in spatial planning and management, and they are used for many kinds of technical assignments. GEUS carries out ongoing geological mapping throughout Denmark. Areas are selected on the basis of society's need for geological data, for example in connection with groundwater abstraction and afforestation. In 2006, field work comprised map projections on the island of Mors, in Fussingø State Forest District and on the island of Lolland. The geological map sheet of the island of Møn in the scale of 1:50 000 was printed in 2006. Geological mapping of Fussingø State Forest District is a part of the basis for forestry and afforestation and the work was partially financed by the Danish Forest and Nature Agency. Finally, 2006 included work on a new edition of the geological overview map of Denmark. This map will be published by Nordisk Kortforlag and will also be available in digital form.

Monitoring of the Greenland ice sheet

The Ministry of the Environment in 2006 decided to commence on systematic monitoring of the Inland Ice. There has long been great uncertainty as to how fast the ice sheet in Greenland is melting, however, new studies show that the rate by which the large glaciers are melting and calving has increased significantly over the past years. The new monitoring activity led by GEUS will focus on what is happening along the edge of the Inland Ice, where the loss of mass from melting and calving of the ice is taking place. Fully automated monitoring stations will be set up at selected locations on the edge of the ice sheet in order to measure the melting, the climate and the ice movement. Glaciologists will supplement the measurements from the surface with measurements from aircraft and satellite. In collaboration with the Technical University of Denmark the ice edge around the entire ice sheet will be measured from aircraft, and the ice movement will be monitored using radar images from the European satellite Envisat. According to the plan, measurements from aircraft will be repeated every second year in order to register the changes systematically. During 2007-2010, monitoring stations will be set up at seven locations along the edge of the entire ice sheet. Monitoring will then be transferred to the operating phase. The Danish monitoring, together with other Danish and international projects in the area, will provide a more precise picture of the consequences of climate change in the Arctic. The project named PROMICE (Programme for Monitoring of the Greenland Ice Sheet) is being financed by the Ministry of the Environment through the DANCEA programme under the Danish Environmental Protection Agency.

International evaluation of GEUS' research

The quality of GEUS' research within the Nature and Environment programme was subject to scrutiny in 2006 by an international panel appointed by the Danish Council for Strategic Research. The review is part of GEUS' ongoing evaluation of the quality of its scientific work. The review resulted in a report, which points to a number of areas, not least the climate area, where GEUS' research, nationally as well as internationally, is of great importance to understanding climate change and its effects. Furthermore, the panel rated the research topics within this area as extremely relevant to society and fulfilling GEUS' commitment to strategic research and its ability to supply advice that can be applied in practice. The Board of Directors of GEUS subsequently expressed great satisfaction with the evaluation, which documents that GEUS' research is of high quality and meets international standards. Apart from a number of general assessments, the report also contains 38 specific recommendations that provide a good foundation for GEUS' future scientific work.

A total of 38 GeoSites designated

With contributions from Danish universities, GEUS in 2006 completed the designation of Danish GeoSites: 38 descriptions of unique geological locations are now available on www.geosites.dk. GeoSites are geological locations of international, scientific value, which document the geological processes and environments that have formed the Earth. The Danish GeoSites include locations such as Stevns Klint, Fakse Quarry, Møns Klint, Hanklit, Lønstrup Klint, Skagen Odde, Gram Lergrav and Åmosen. Together, the 38 sites document important geological characteristics such as abrupt changes in the environment, well-preserved fossils, unique minerals, the impact of the ice on the landscape, clear traces of prehistoric climate, and the formation of unique coastlines. The objective of identifying GeoSites is to create more awareness about unique geological values and help nurture and protect them. The International Union of Geological Sciences (IUGS) has instigated the work, and Danish efforts were set in motion by the Danish National Committee of Geology and GEUS. Countries throughout Europe are designating GeoSites, and Denmark is in the lead of the European process with the designation of the 38 sites.

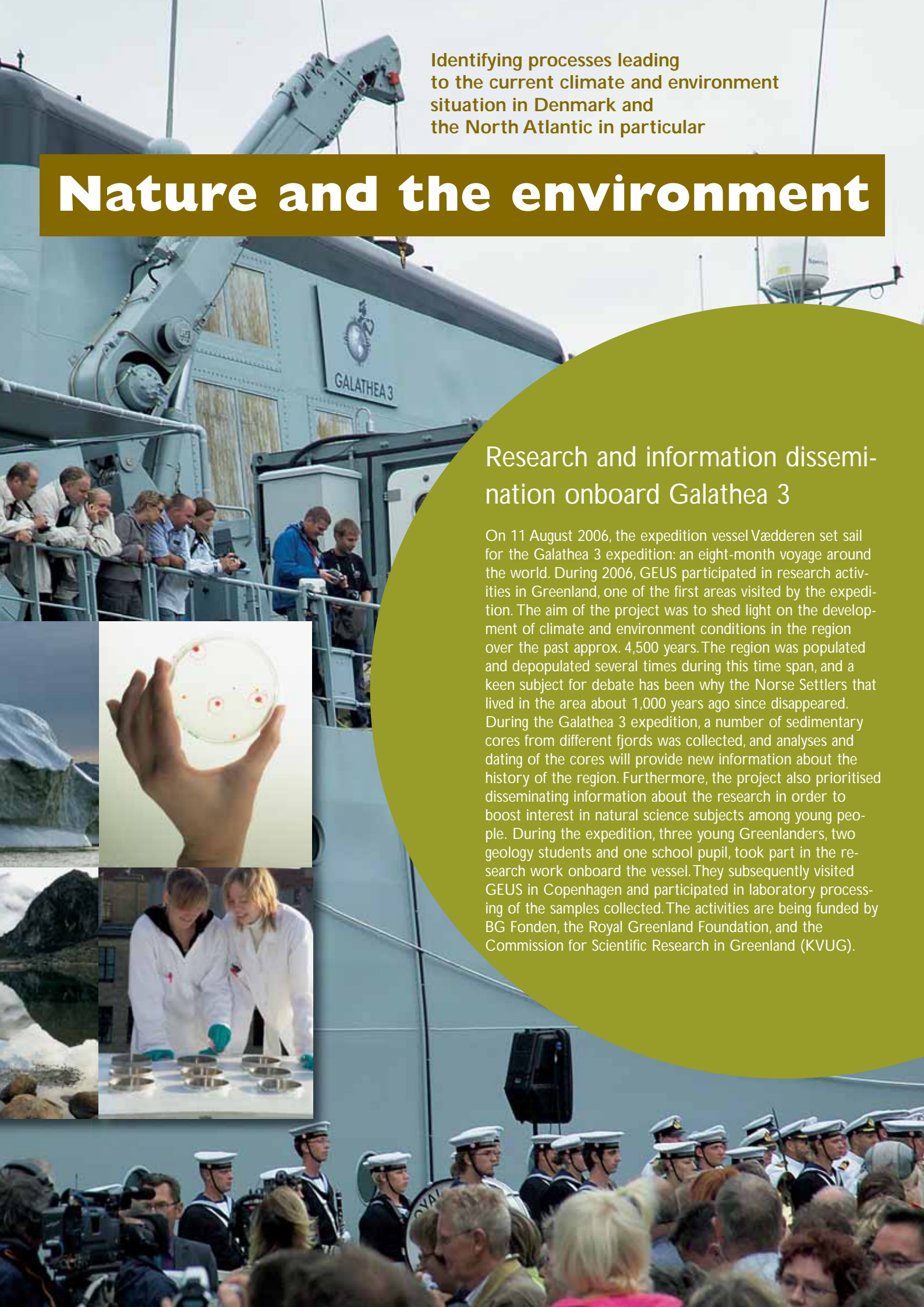


Identifying processes leading to the current climate and environment situation in Denmark and the North Atlantic in particular

Nature and the environment

Research and information dissemination onboard Galathea 3

On 11 August 2006, the expedition vessel *Vædderen* set sail for the Galathea 3 expedition: an eight-month voyage around the world. During 2006, GEUS participated in research activities in Greenland, one of the first areas visited by the expedition. The aim of the project was to shed light on the development of climate and environment conditions in the region over the past approx. 4,500 years. The region was populated and depopulated several times during this time span, and a keen subject for debate has been why the Norse Settlers that lived in the area about 1,000 years ago since disappeared. During the Galathea 3 expedition, a number of sedimentary cores from different fjords was collected, and analyses and dating of the cores will provide new information about the history of the region. Furthermore, the project also prioritised disseminating information about the research in order to boost interest in natural science subjects among young people. During the expedition, three young Greenlanders, two geology students and one school pupil, took part in the research work onboard the vessel. They subsequently visited GEUS in Copenhagen and participated in laboratory processing of the samples collected. The activities are being funded by BG Fonden, the Royal Greenland Foundation, and the Commission for Scientific Research in Greenland (KVUG).



Two new professorships

GEUS got two new professors in 2006. Carsten Suhr Jacobsen was appointed as research professor in geomicrobiology at the Department of Geochemistry at GEUS. The appointment is a collaborative professorship with the Department of Natural Sciences at the University of Copenhagen, where Carsten Suhr Jacobsen will be arranging and participating in teaching activities some of the time. The collaborative professorship is to develop and strengthen the geomicrobiological and molecular-biological subject area, ensure integration with the geo-professional environment and enhance GEUS' collaboration activities with the University of Copenhagen in the fields of teaching and research. The other new professor at GEUS is Niels Peter Christensen, who in November was appointed honorary professor in CO₂ storage at the Heriot-Watt University, Edinburgh Scotland, Institute for Petroleum Engineering.

Glimpses of the year

Environment and climate advisor for the European Commission

Senior researcher Naja Mikkelsen (MSc, PhD) from GEUS was appointed scientific advisor for the European Commission in July 2006. Along with 19 other environment researchers from the EU, she will be giving advice on the basis of her personal assessment about the EU's overall prioritisations within environment and climate research. Naja Mikkelsen is well-acquainted with the international research environment and has many years of experience within Arctic research.



A geological year

In 2006, Danes had ample opportunity to get to know more about Denmark's geology and hear interesting research stories about the Earth that sustains us. The Geology Days, the last weekend of September, a total of 56 excursions and events throughout Denmark attracted many Danes. At coastlines, in gravel pits and hilly landscapes, geology experts from all over Denmark were ready to tell exciting stories about the geological wonders of Denmark. Furthermore, during Research Day in May and the Danish Science Festival in September, geologists from GEUS visited schools, libraries, enterprises and associations throughout Denmark to tell about earthquakes, tsunamis, groundwater and dramatic changes in the polar ice sheets. The last big event of the year took place in October during the Night of Culture in Copenhagen, when more than 2,000 visitors went through the turnstile at the Geological Museum, in order to participate in the treasure hunt for gold and diamonds in Greenland in the company of geologists from GEUS.



Research collaboration agreement in Greenland

On Wednesday 31 May 2006, the US Geological Survey (USGS), GEUS and the Bureau of Minerals and Petroleum under the Greenland Home Rule signed an agreement about scientific and technical collaboration on geological research in Greenland. The event took place at the Geological Museum in Copenhagen in the presence of more than 60 diplomats, officials and researchers from the US, Greenland and Denmark. The agreement was signed by the US ambassador to Denmark, the Executive Deputy Ministers of the Greenland Government and GEUS. The agreement is part of a larger collaboration agreement from 2004 between Greenland, Denmark and the US, the objective of which is to provide collaboration on specific projects in Greenland within the environment, science, health, technology, education, culture, trade and tourism.



New doctorate at GEUS

Senior researcher Stig A. Schack Pedersen attained his doctoral degree in natural science in 2006. On 10 March 2006, he delivered his oral defence of his dissertation entitled 'Structural analysis of the Rubjerg Knude Glaciotectonic Complex, Vendsyssel, northern Denmark', which contains an analysis of the structures in ice-age layers in Lønstrup Klint in Vendsyssel, formed during the advance of the Scandinavian Ice Sheet, 26,000-30,000 years ago.

Large new appropriations from the National Advanced Technology Foundation

GEUS is participating in two out of 13 research projects that the Danish National Advanced Technology Foundation launched in 2006 between enterprises and Danish research institutions. All the projects combine specific research and business challenges and hold potential for creating new growth industries. The first project, Sustainable Construction Materials for the Future (FUTURE-CEM), is to carry out research in new functional nanoparticles for use in the manufacture of new types of cement and construction materials. Today, cement is manufactured in a process where the raw materials are heated to very high temperatures. The objective of the project is to increase the production capacity and at the same time reduce energy consumption and CO₂ emission significantly. The project therefore has a great environmental and financial potential, as cement manufacture is an industry in strong growth globally. GEUS is contributing unique knowledge about layer silicate minerals in nanosize to the project and holds expertise to develop nanoparticles which can improve the nanostructure and properties of the cement. Project partners include Aalborg Portland Group, iNANO and the Interdisciplinary Nanoscience Center at the Universities of Aarhus and Aalborg. The other project, Environment-Friendly Oil Recovery through CO₂-injection, is to examine the possibilities for pumping CO₂ from power plants into North Sea oil reservoirs. CO₂ dilutes the oil and makes it flow more easily to the production wells. In this way, one can increase oil recovery efficiency and store the CO₂ underground at the same time, solving two major problems simultaneously: reducing emission of CO₂ to the atmosphere and increasing oil recovery from existing oilfields. GEUS is contributing to the project with several years of experience in examining reservoir rock types in oilfields on the basis of drill cores, and the research will cover laboratory examinations of drill cores to predict how an oilfield will react if pumped with CO₂. Project partners include DONG E&P A/S, DONG Energy Generation, the Department of Chemical Engineering and the Institute of Environment & Resources at the Technical University of Denmark, and GEO (Danish Geotechnical Institute).





Photo:
Dorte F. Pedersen



More environment-friendly small-scale mining in Tanzania

Small-scale mining provides a living for up to 100 million people around the world. Gold mining in particular creates many jobs. The mining takes place with tremendously primitive methods, where gold miners use mercury to extract the gold, a method harmful to the environment as well as to the health of the miners. In Tanzania, efforts to introduce the use of a small, simple apparatus, called a retort, which reuses the mercury during the extraction of the gold, have so far been unsuccessful. GEUS is participating in a research project which is mapping this problem and suggesting solutions. In the course of 2006, however, through continuous dialogue with and training of the miners, the project was successful in introducing the use of retorts in two selected communities. Eighteen of twenty miners have used the retort for a period of more than five months, and during this period, a total of 10 kg of mercury was recycled. The studies in Tanzania are part of a PhD programme at the Department of Geography and Geology at the University of Copenhagen, the activities are being funded by Geocenter Copenhagen.



Ten years of oil training in Vietnam

In May 2006, the ten-year anniversary of a Vietnamese-Danish research collaboration programme was celebrated with a ceremony at GEUS. During the ten years the programme has run, the Vietnam Petroleum Institute (VPI) and GEUS have carried out several collaboration projects to help the Vietnamese assess their country's oil and gas resources. Research, technology transfer and training at VPI and at GEUS in Copenhagen were key parameters in the projects. 2006 was also the second year of the most recent collaboration project between VPI and GEUS: Integrated Analysis and Modelling of Geological Basins in Vietnam and Assessment of their Hydrocarbon Potential. This project, which is financed by the ENRECA programme under DANIDA (Danish International Development Assistance), builds on previous experience from the ENRECA project where Vietnamese researchers were trained in oil-geological disciplines and carried out specific research projects. The project focuses on oil-geological research in the Malay-Tho Chu Basin, with a view to understanding the geological structure of the basin and assessing the potential for oil/gas. The project not only aims at capacity-building at VPI, but also at improving cooperation with universities in Vietnam and Denmark. With participation from teaching resources from the Department of Geography and Geology at the University of Copenhagen, there are joint MSc/PhD programmes for younger researchers and students from VPI, Hanoi University of Mining and Geology (HUMG) and the Hanoi University of Science (HUS). The programmes were in good use throughout the year. Six PhD students completed longer courses in Copenhagen with great success. They completed oil-geological courses at the University of Copenhagen and job training at GEUS, and all nine PhD students in the PhD programme have now completed this part of their training. In the beginning of 2006, a 504 m deep ENRECA-2 borehole was drilled on the island Phu Quoc. Furthermore, field work was carried out on the island in order to put the results from the drilling into their geological context. Teaching students and other individuals from the geological environment in Vietnam has been an important part of the work and the subsequent borehole logging and descriptions of drill cores. Finally, during the year, Vietnamese and Danish researchers presented results from the collaboration project at meetings in Vietnam and at international conferences in Australia, Japan and Austria.



GEUS around the world

Knowledge building in developing countries
through research and consultancy



Tsunami contingency plan in Kenya

The tsunami which caused death and mayhem in Southeast Asia on 26 December 2004 also reached the coast of East Africa. The effect of the wave along the coast of Kenya was limited because of the great distance to the epicentre of the earthquake and because the waves hit at low tide when large parts of the coast were protected by coral reefs. In 2005 and 2006, a Danish- Kenyan project assessed the consequences of a tsunami, should one hit Kenya during less favourable conditions. Using improved contour lines and model calculations, the effect of a tsunami on the coast during high tide was calculated for a tsunami similar to the one in 2004, and for a worst-case scenario with 50 percent stronger waves. The result was a series of maps that show the extent of the flooding and the power of the water masses, as well as whether vital institutions such as hospitals, police stations and industrial areas are situated within the affected zone. Furthermore, socio-economic assessments of the consequences for fisheries, tourism, agriculture, industry, water supply, mining operation, cultural heritage and infrastructure (roads, bridges, harbours) were carried out. Assessments were inclusive of deaths and financial consequences. The project results will be used by Kenyan authorities in their work to improve the country's tsunami contingency plan should a powerful tsunami hit the coast in the future. The project is being run by GEUS. The company AquaSim and the organisation DEPHA from Kenya are taking part in the project, which is being funded by DANIDA through the United Nations Development Programme (UNDP).

Progress in research to combat arsenic pollution

The groundwater pumped up from the flood plain around the Red River near Hanoi in Vietnam in many places is polluted with arsenic. Arsenic occurs naturally in sediments in the flood plain, but different processes in the groundwater system can mobilise arsenic so that it ends in the groundwater. Due to the good bacteriological quality of groundwater, about 50 per cent of water supplies for Hanoi are based on this resource, but arsenic pollution now poses a threat to this supply. The problem was addressed by the GEUS-run project VietAs in 2005 and 2006, where Danish and Vietnamese researchers examined the processes that lead to contamination in selected test areas. These examinations have found that mobilisation of the arsenic is associated, in particular, with geological layers with a high organic content and access to oxygen, and that occurrences of arsenic are also dependent on water flow in the sediments from flooding of the flood plain. These results are a good vantage point for identifying future sites for wells where the risk of groundwater contamination with arsenic is minimal. The project aims at research and capacity development, and more than ten Vietnamese students are participating in the MSc programmes. During 2006, several students took courses at the Technical University of Denmark and received special guidance at GEUS. The project is being funded by the Danish Research Council for Development Research under DANIDA and is a collaboration project between the Technical University of Denmark and DHI Water & Environment, as well as Hanoi University of Mining and Geology, Hanoi University of Science and the Northern Hydrological and Engineering Geological Division.



Key figures

Number of employees: **291**

Number of scientific projects: approx. **500**

ACCOUNTS 2006

Amounts in million DKK

Revenue:	277.3
Net figure (appropriation):	129.5
Operating income:	141.7
Expenditure:	272.2
Salaries	130.5
Other operating expenditure:	141.7

PRESENTATION ACTIVITIES

Long-term knowledge building

Articles in international scientific journals/publications	101
Articles in GEUS' own scientific series	48
Other scientific publications	12

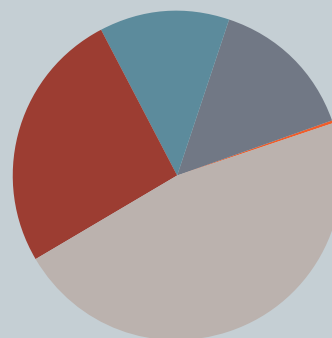
Ongoing scientific task solution, consultancy and presentation

Publicly available reports	85
Confidential reports	35
Memoranda, opinions, expositions, etc.	41
General presentation	
Institution reports (annual report, etc.)	6
General and popular-science articles	131
Popular-science lectures	66
Visits on www.geus.dk	1.800.000

Researcher training

PhD students with GEUS tutors	37
Completed PhD degrees at GEUS	5

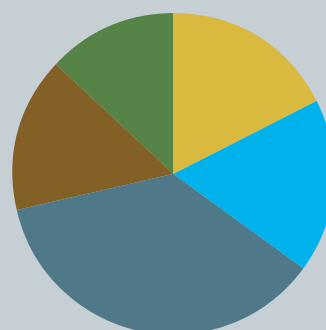
Revenue broken down by resources of revenue:



Amounts in million DKK

Budget appropriation:	129.5
Programme and external resources:	72.3
Other co-financed contract research:	35.4
Commercial contracts and sale of data:	39.4
Other revenue:	0.7

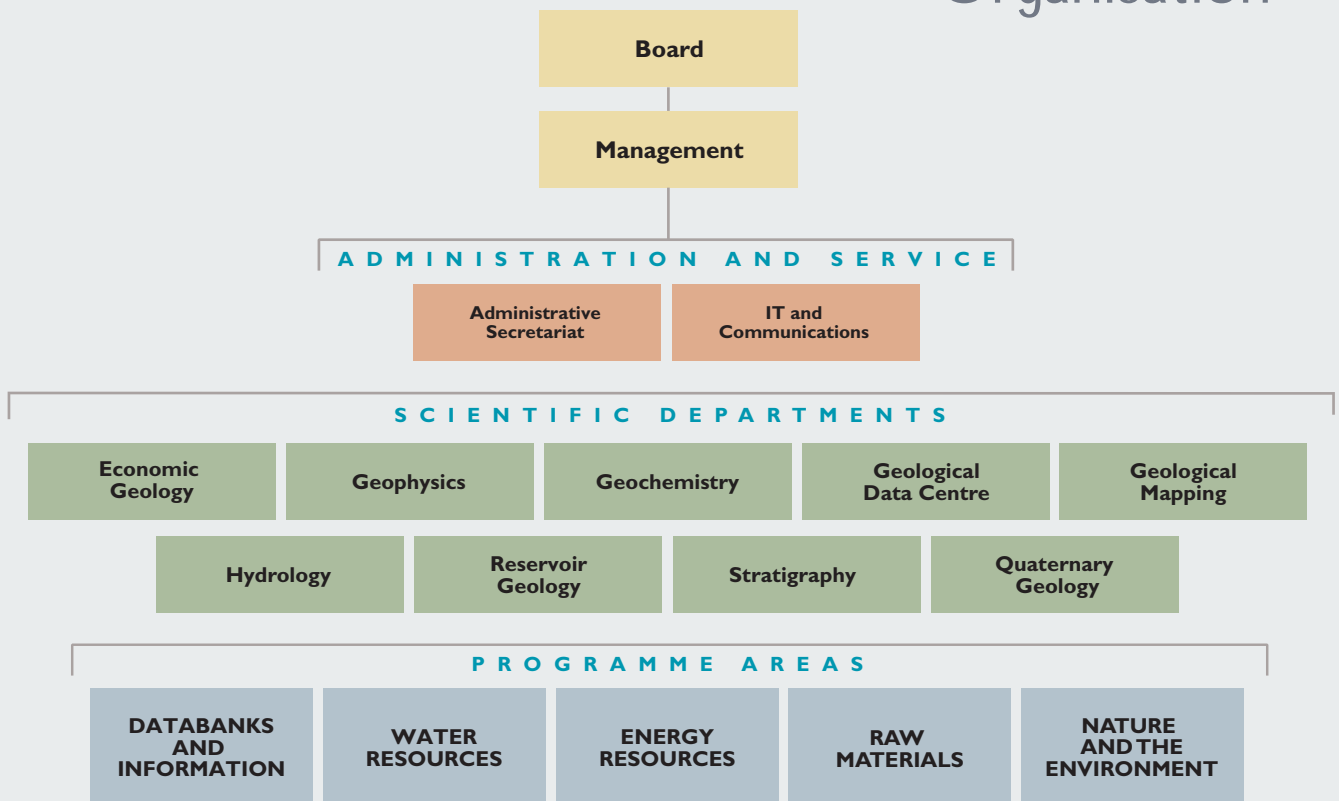
Expenditure broken down after programme areas:



Amounts in million DKK

Databanks and information:	48.2
Water resources:	47.5
Energy resources:	98.6
Mineral resources:	42.6
Nature and the environment:	35.2

Organisation



In 2006, GEUS had nine research departments and two administrative/service departments. Scientific work takes place in five programme areas, where tasks are carried out in project groups in a matrix structure.

Programme area: Databanks and information

Archiving and data processing in connection with statutory reporting of geo-data to GEUS. The objective is to ensure that data and sample collections are on a quality level allowing them to be used to implement projects in the areas of monitoring, emergency preparedness, consultancy and research. In addition, the programme area includes IT projects to develop efficient and modern IT tools for GEUS and presentation of data to the scientific community and the public.

Programme area: Water resources

Procuring the necessary basis on which to manage our water resources. Activities are aimed at water circulation, the volume and quality of water resources, groundwater protection and trans-

portation of substances injurious to the water environment with special emphasis on groundwater. The activities form the basis of consultancy services to government and local authorities.

Programme area: Energy resources

Procuring and contributing the basis for continued exploration and sustainable exploitation of the energy resources of Denmark and Greenland. Activities include own research projects and international co-operation in the areas of oil/gas and alternative energy. The knowledge retrieved forms the basis of GEUS' consultancy services to government and local authorities and to some extent projects carried out for the corporate sector.

Programme area: Mineral resources

Procuring the scientific basis for targeted exploration and environment-friendly exploitation of raw materials and minerals in Greenland and Denmark. Activities include geological mapping and exploration of mineral resources in

Greenland and official processing and consultancy services for Greenland Home Rule. In addition, studies are conducted regarding raw materials and construction work in Denmark and internationally.

Programme area: Nature and the environment

Identifying the processes in time and space leading to the current climate and environmental situation in Denmark and the North Atlantic region in particular. One objective is to improve the prospect of distinguishing between natural and man-made environmental changes. This programme area also includes mapping of onshore and offshore geological conditions, as well as earthquake research and monitoring.

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